

INDEPENDENT ORBITER ASSESSMENT

ANALYSIS OF THE ELECTRICAL POWER GENERATION/FUEL CELL POWERPLANT SUBSYSTEM

5 DECEMBER 1986

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HOUSTON DIVISION

SPACE TRANSPORTATION SYSTEM ENGINEERING AND OPERATIONS SUPPORT

WORKING PAPER NO. 1.0-WP-VA86001-10

INDEPENDENT ORBITER ASSESSMENT
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POWERPLANT SUBSYSTEM

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This Working Paper is Submitted to NASA under
Task Order No. VA86001, Contract NAS 9-17650

PREPARED BY: K.L. Brown
K.L. Brown
Lead Analyst
Independent Orbiter
Assessment

APPROVED BY: M.R. Hiott
M.R. Hiott
EPG/FCP Lead
Independent Orbiter
Assessment

PREPARED BY: P.J. Bertsch
P.J. Bertsch
Lead Analyst
Independent Orbiter
Assessment

APPROVED BY: G.W. Knori
G.W. Knori
Technical Manager
Independent Orbiter
Assessment

APPROVED BY: W.F. Huning
W.F. Huning
Deputy Program Manager
STSEOS

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Independent Orbiter Assessment
Analysis of the Electrical Power Generation/Fuel
Cell Powerplant Subsystem

1.0 EXECUTIVE SUMMARY

The McDonnell Douglas Astronautics Company (MDAC) was selected in June 1986 to perform an Independent Orbiter Assessment (IOA) of the Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL). Direction was given by the STS Orbiter and GFE Projects Office to perform the hardware analysis using the instructions and ground rules defined in NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. The IOA approach features a top-down analysis of the hardware to determine failure modes, criticality, and potential critical items. To preserve independence, this analysis was accomplished without reliance upon the results contained within the NASA FMEA/CIL documentation. This report documents (Appendix C) the independent analysis results corresponding to the Orbiter Electrical Power Generation (EPG)/Fuel Cell Powerplant (FCP) hardware.

The EPG/FCP hardware is required for performing functions of electrical power generation and product water distribution in the Orbiter. Specifically, the EPG/FCP hardware consists of the following divisions:

- o Power Section Assembly (PSA)
- o Reactant Control Subsystem (RCS)
- o Thermal Control Subsystem (TCS)
- o Water Removal Subsystem (WRS)

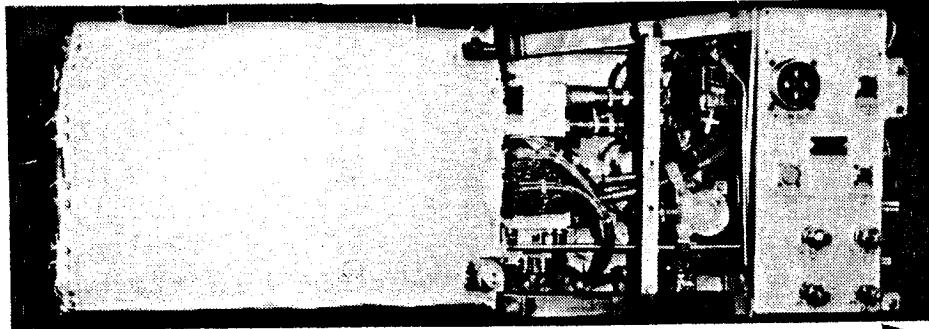
The IOA analysis process utilized available EPG/FCP hardware drawings and schematics for defining hardware assemblies, components, and hardware items. Each level of hardware was evaluated and analyzed for possible failure modes and effects. Criticality was assigned based upon the severity of the effect for each failure mode.

Figure 1 presents the failure criticalities for the four major divisions of the two FCP assemblies. A summary of the number of failure modes, by criticality, is also presented below with Hardware (HW) criticality first and Functional (F) criticality second.

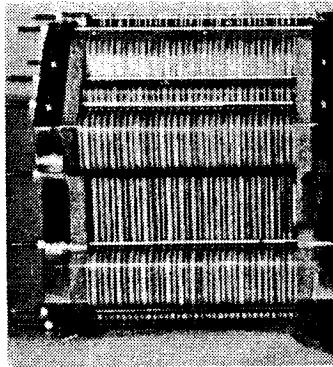
| Summary of IOA Failure Modes By Criticality (HW/F) | | | | | | | |
|--|-----|------|-----|------|------|-----|-------|
| Criticality: | 1/1 | 2/1R | 2/2 | 3/1R | 3/2R | 3/3 | TOTAL |
| Number : | 3 | 26 | - | 10 | 4 | 19 | 62 |

EPG/FCP OVERVIEW ANALYSIS SUMMARY

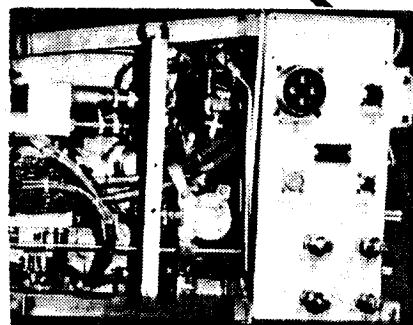
| EPG/FCP ANALYSIS SUMMARY | | | | | |
|--------------------------|-----|------|------|-----|------|
| CRIT | #FM | #PCI | CRIT | #FM | #PCI |
| 1/1 | 3 | 3 | 3/2R | 4 | 3 |
| 2/1R | 26 | 26 | 3/3 | 19 | NA |
| 3/1R | 10 | 0 | | | |



POWER SECTION



ASSESSORY SECTION



POWER SECTION ASSEMBLY

| CRIT | #FM | #PCI |
|------|-----|------|
| 1/1 | 2 | 2 |
| 2/1R | 5 | 5 |
| 3/3 | 1 | NA |

THERMAL CONTROL SUBSYSTEM

| CRIT | #FM | #PCI |
|------|-----|------|
| 2/1R | 5 | 5 |
| 3/1R | 2 | 0 |
| 3/3 | 4 | NA |

WATER REMOVAL SUBSYSTEM

| CRIT | #FM | #PCI |
|------|-----|------|
| 2/1R | 9 | 9 |
| 3/1R | 4 | 0 |
| 3/2R | 4 | 3 |
| 3/3 | 9 | NA |

CRIT - CRITICALITY

FM - FAILURE MODE

PCI - POTENTIAL CRITICAL ITEM

NA - NOT APPLICABLE

Figure 1 - EPG/FCP OVERVIEW ANALYSIS SUMMARY

For each failure mode identified, the criticality and redundancy screens were examined to identify critical items. A summary of Potential Critical Items (PCIs) is presented as follows:

| Summary of IOA Potential Critical Items (HW/F) | | | | | | |
|--|-----|------|-----|------|------|-------|
| Criticality: | 1/1 | 2/1R | 2/2 | 3/1R | 3/2R | TOTAL |
| Number : | 3 | 26 | - | - | 3 | 32 |

2.0 INTRODUCTION

2.1 Purpose

The 51-L Challenger accident prompted the NASA to readdress safety policies, concepts, and rationale being used in the National Space Transportation System (NSTS). The NSTS Office has undertaken the task of reevaluating the FMEA/CIL for the Space Shuttle design. The MDAC is providing an independent assessment of the Orbiter FMEA/CIL for completeness and technical accuracy.

2.2 Scope

The scope of the independent FMEA/CIL assessment activity encompasses those Shuttle Orbiter subsystems and GFE hardware identified in the Space Shuttle Independent FMEA/CIL Assessment Contractor Statement of Work. Each subsystem analysis addresses hardware, functions, internal and external interfaces, and operational requirements for all mission phases.

2.3 Analysis Approach

The independent analysis approach is a top-down analysis utilizing as-built drawings to breakdown the respective subsystem into components and low-level hardware items. Each hardware item is evaluated for failure mode, effects, and criticality. These data are documented in the respective subsystem analysis report, and are used to assess the NASA and Prime Contractor FMEA/CIL reevaluation results. The IOA analysis approach is summarized in the following Steps 1.0 through 3.0. Step 4.0 summarizes the assessment of the NASA and Prime Contractor FMEAs/CILs that is performed and documented at a later date.

Step 1.0 Subsystem Familiarization

- 1.1 Define subsystem functions
- 1.2 Define subsystem components
- 1.3 Define subsystem specific ground rules and assumptions

Step 2.0 Define subsystem analysis diagram

- 2.1 Define subsystem
- 2.2 Define major assemblies
- 2.3 Develop detailed subsystem representations

Step 3.0 Failure events definition

- 3.1 Construct matrix of failure modes
- 3.2 Document IOA analysis results

Step 4.0 Compare IOA analysis data to NASA FMEA/CIL

- 4.1 Resolve differences**
- 4.2 Review in-house**
- 4.3 Document assessment issues**
- 4.4 Forward findings to Project Manager**

2.4 EPG/FCP Ground Rules and Assumptions

The EPG/FCP ground rules and assumptions used in the IOA are defined in Appendix B.

3.0 SUBSYSTEM DESCRIPTION

3.1 Design and Function

The EPG/FCP consists of hardware that is required for electrical power generation and Fuel Cell (FC) product water collection and distribution in the Orbiter. Reference Figures 2 and 3. The EPG/FCP consists of the following divisions:

1. The Power Section Assembly (PSA) which is also called Cell Stack Assembly (CSA) combines hydrogen and oxygen through an electrochemical conversion to produce electrical power, water, and heat. Each PSA cell stack consists of cell plates, pressure plates, end cell heater/insulator plates, tie rods, and individual cell voltage harness. Each cell plate is made up of Unitized Electrode Assembly (UEA) and separator plates. The cell stack consists of 96 cell plates grouped electrically into three substacks connected in parallel. The substack contains 32 cell plates connected electrically in series. The PSA also contains a cell performance monitor which provides continuous analog data outputs to the Orbiter. The outputs transmit individual cell performance problems or imminent failures. Reference Figure 4.
2. The Reactant Control Subsystem (RCS) consists of preheaters, coupled reactant regulator, hydrogen pump-separator, condenser, hydrogen/water purge/vent line and oxygen purge/vent line. The RCS heats cryogenic-temperature gaseous reactants (oxygen and hydrogen) from the Power Reactant Storage and Distribution System (PRSDS) to an acceptable temperature for delivery to the coupled reactant regulator. The RCS delivers reactant gases to the PSA on demand and controls the reactant pressure within the cell plates. The RCS provides for purging of inert gases from reactant lines. The RCS circulates hydrogen for water removal from the PSA and also prevents water from entering the PSA. Reference Figure 5.
3. The Thermal Control System (TCS) contains a coolant pump, thermal control valve, coolant accumulator, start/sustaining heater, and condenser. The TCS controls the FCP operating temperatures and electrolyte concentration. The TCS removes waste heat from the PSA and heat from the moist hydrogen recycle flow to condense water vapor. The TCS transfers heat to the inlet reactant gases passing through preheaters and rejects heat to the Orbiter vehicle cooling system. Reference Figure 6.
4. The Water Removal Subsystem (WRS) consists of a condenser, hydrogen pump-separator, water purity sensor,

water trap and water discharge line. The WRS removes water produced in the PSA during the FCP operation. The FCP produces water vapor which is converted to a liquid in the condenser. The hydrogen pump-separator centrifugally separates the water from the hydrogen. The WRS delivers the water to the Orbiter vehicle potable water storage system or to the water relief line. Reference Figure 7.

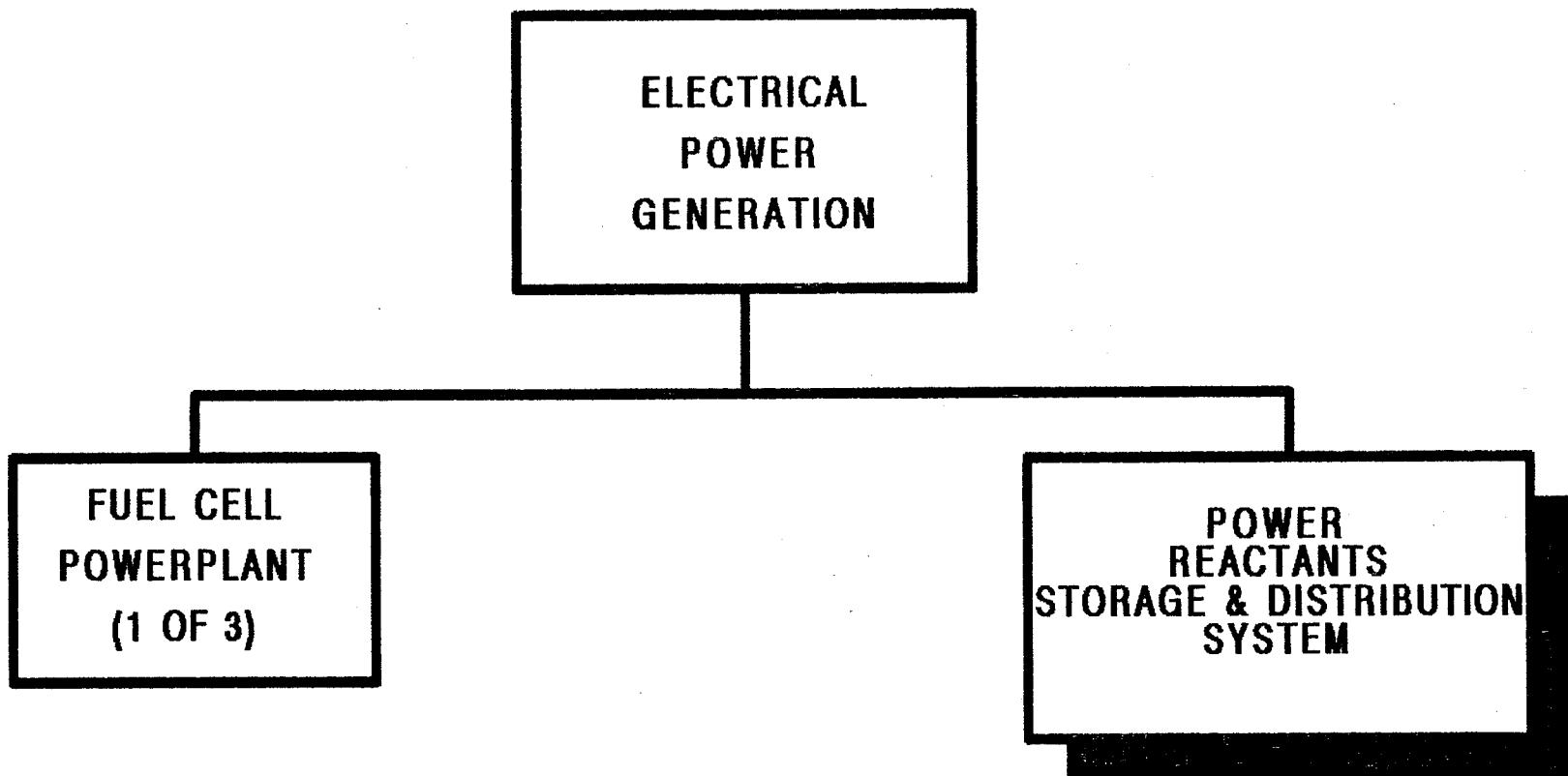
3.2 Interfaces and Locations

The three EPG/FCPs are installed in the mid-body of the Orbiter beneath the payload bay liner. Fuel Cell 1 (FC1) is located on the left-hand side of the payload bay. Whereas, FC2 and FC3 are located forward and aft respectively, on the right-hand side of the payload bay. Reference Figure 8. The FCPs PSA receives the hydrogen and oxygen reactants from the Power Reactants Stowage and Distribution System (PRSDS). The product water from the PSA is transported to the Environmental Control and Life Support System (ECLSS) for stowage. The waste heat produced by the PSA is rejected to the Orbiter vehicle cooling system through the FC40 coolant in the TCS. The FCP receives three phase AC electrical power from the Orbiter to power the coolant pump, hydrogen pump-separator, and the water purity sensor. The FCP generates DC electrical power which is distributed to the Orbiter electrical power system. Reference Figure 9.

3.3 Hierarchy

Figures 2 and 3 illustrate the hierarchy of the EPG and FCP systems, respectively. The FCP subsystems are depicted in Figures 4 through 7.

ELECTRICAL POWER GENERATION SUBSYSTEM OVERVIEW



*EPG INTERFACE BUT NOT
CONSIDERED IN THIS ANALYSIS*

Figure 2 – EPG SUBSYSTEM OVERVIEW

FUEL CELL POWER PLANT SUBSYSTEM OVERVIEW

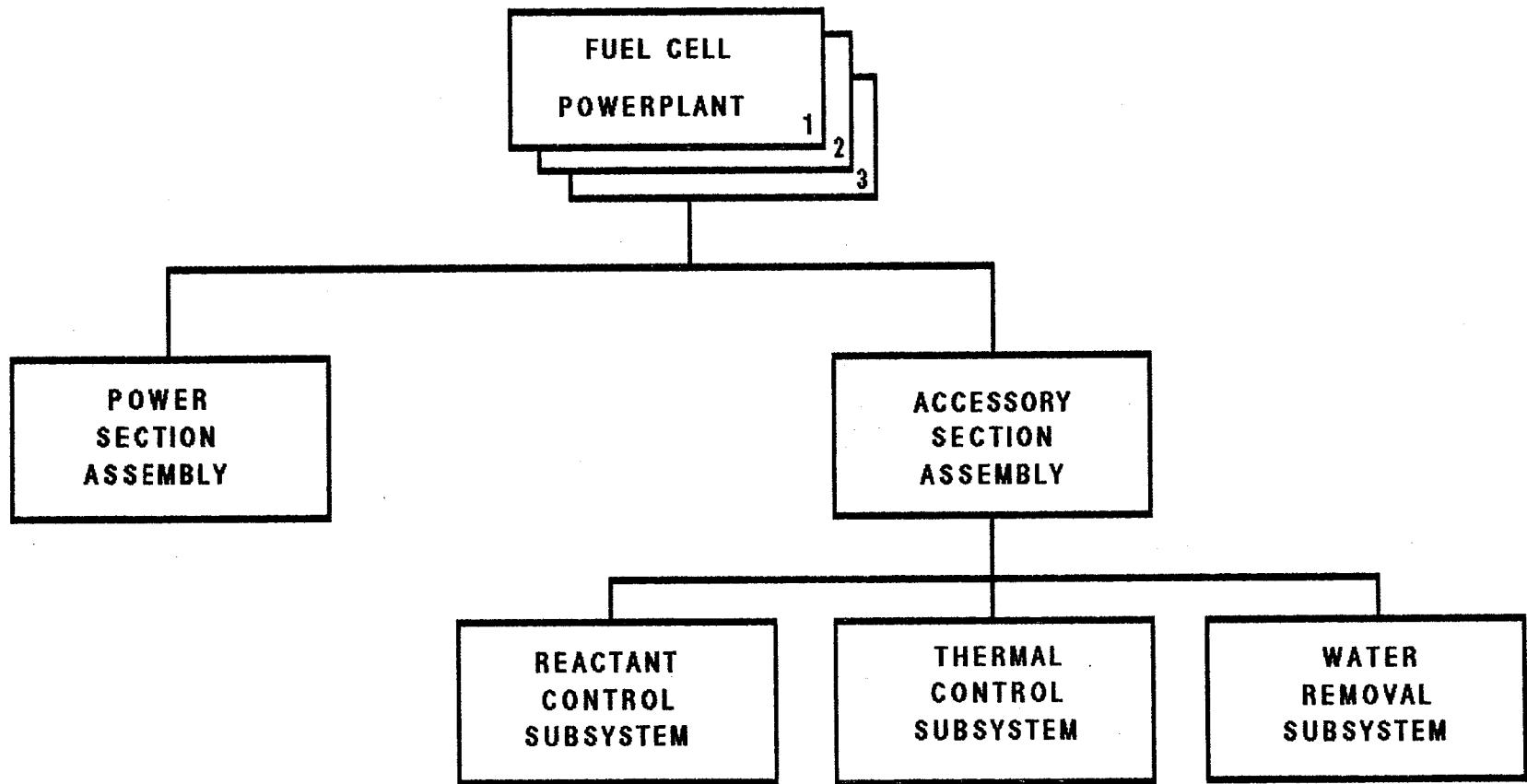
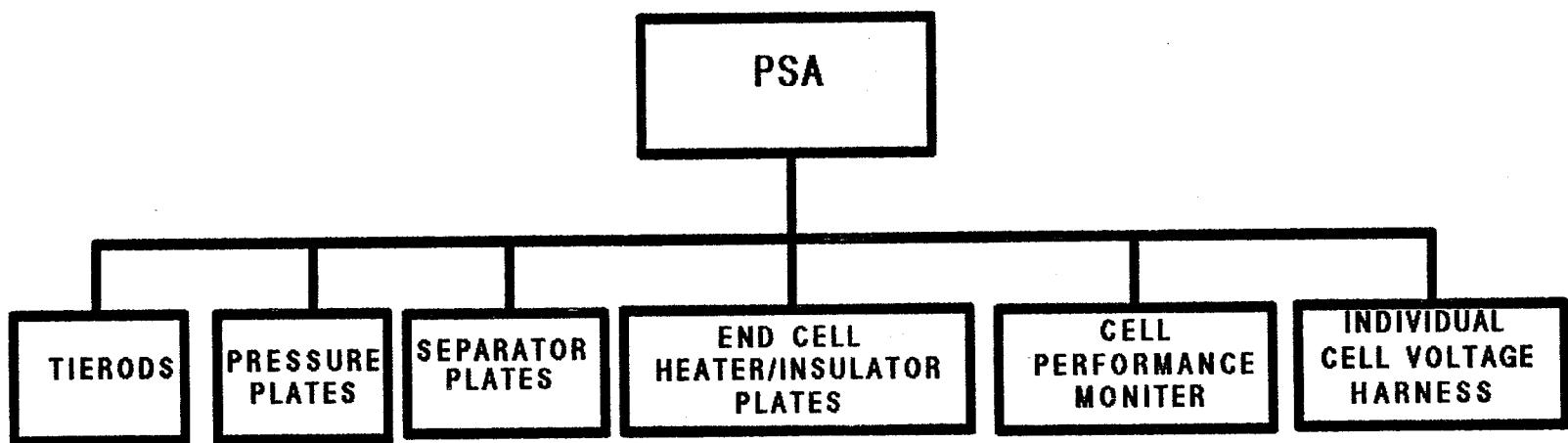


Figure 3 - FCP SUBSYSTEM OVERVIEW

FCP POWER SECTION ASSEMBLY



FCP REACTANT CONTROL SUBSYSTEM

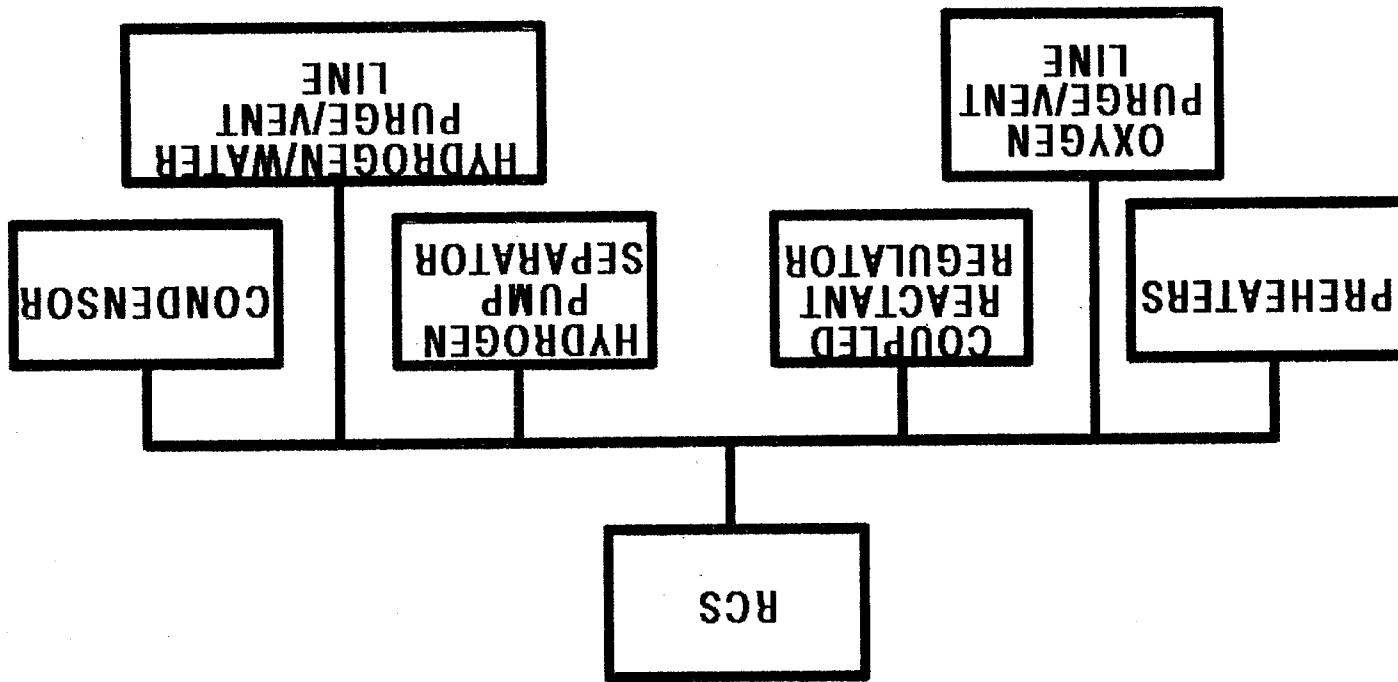


Figure 5 - FCP REACTANT CONTROL SUBSYSTEM (RCS)

FCP THERMAL CONTROL SUBSYSTEM

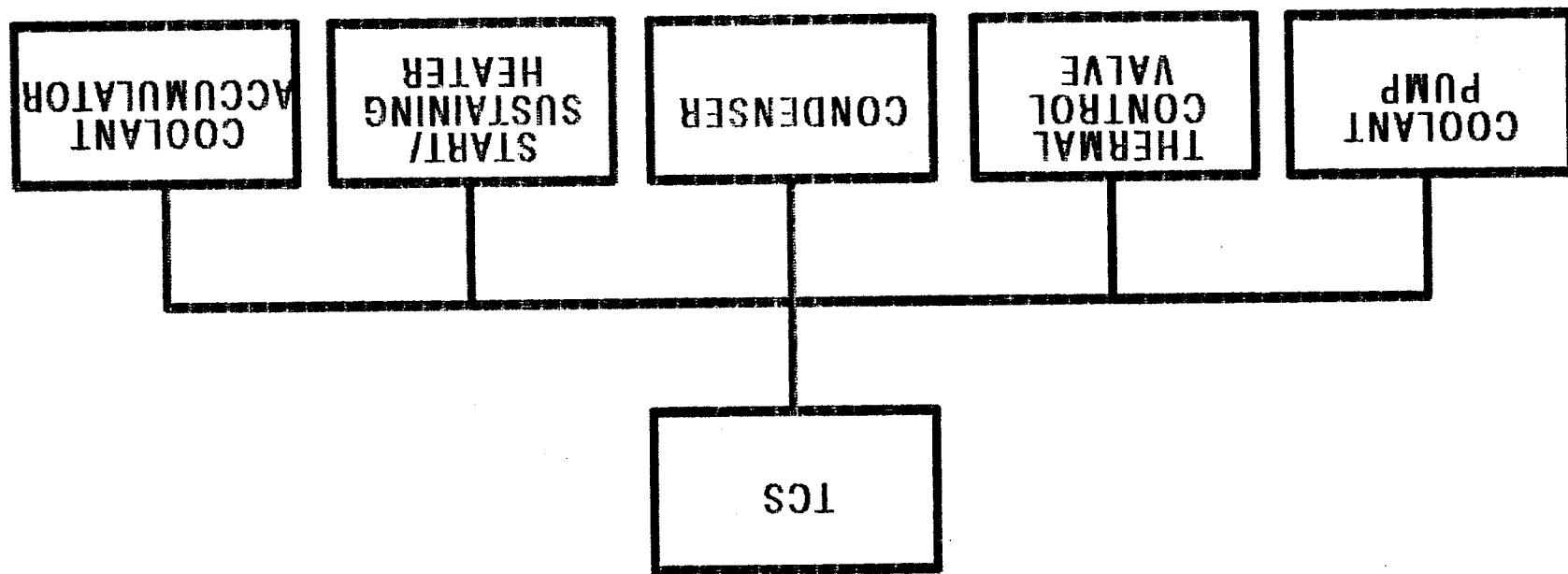


Figure 6 - FCP THERMAL CONTROL SUBSYSTEM (TCS)

FCP WATER REMOVAL SUBSYSTEM

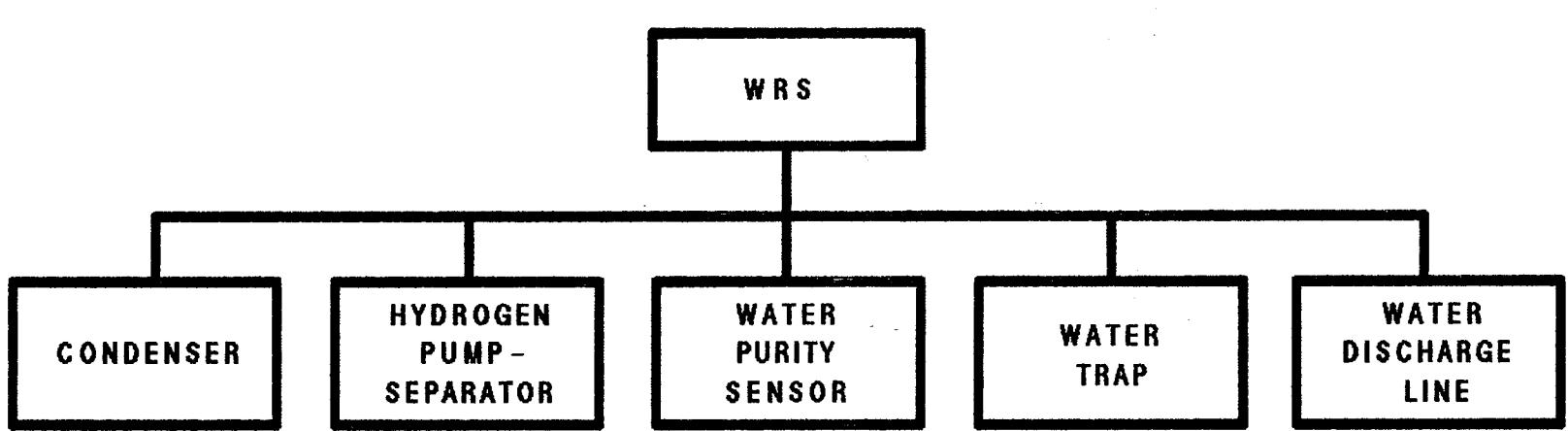
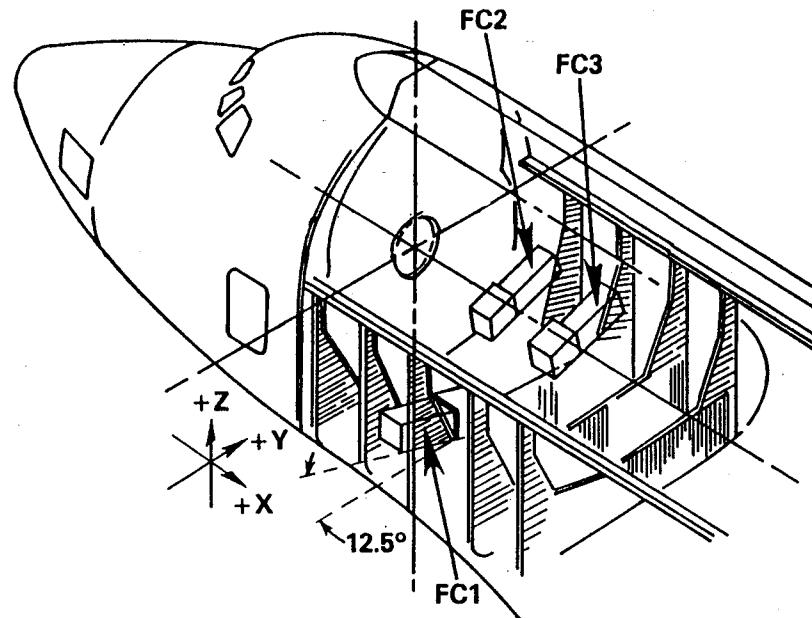


Figure 7 – FCP WATER REMOVAL SUBSYSTEM (WRS)

FUEL CELL POWERPLANT LOCATION IN THE ORBITER VEHICLE



- O Three Orbiter FCP's installed in the Orbiter vehicle mid - body beneath the payload liner
 - FC1 installed on left - hand side
 - FC2 installed forward on right - hand side
 - FC3 installed aft on right - hand side

Figure 8 - FCP LOCATION IN THE ORBITER VEHICLE

FCP LOCATION AND INTERFACES

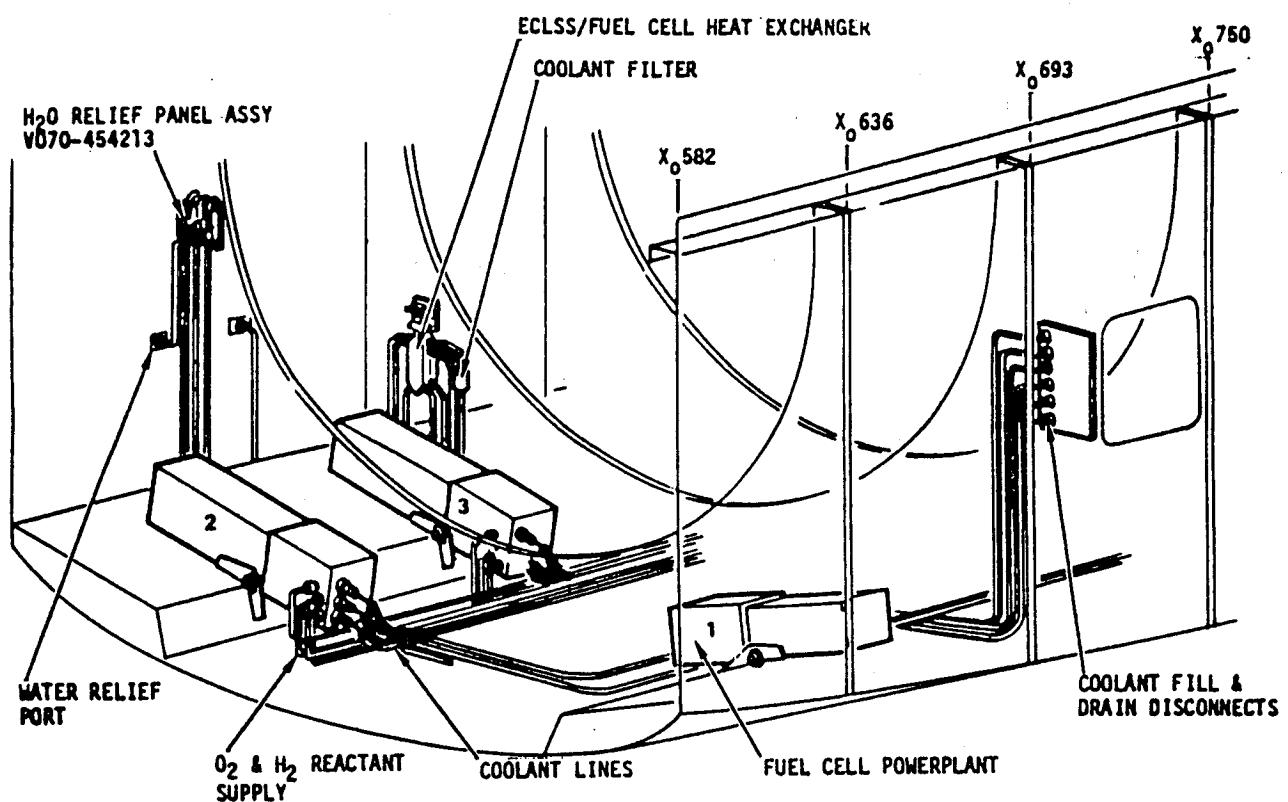


Figure 9 - FCP LOCATION AND INTERFACES

4.0 ANALYSIS RESULTS

Detailed analysis results for each of the identified failure modes are presented in Appendix C. Table I presents a summary of the failure criticalities for each of the four major subdivisions of the EPG/Fuel Cell. Further discussion of each of these subdivisions and the applicable failure modes is provided in subsequent paragraphs.

| TABLE I Summary of IOA Failure Modes and Criticalities | | | | | | | |
|--|-----|------|-----|------|------|-----|-------|
| Criticality: | 1/1 | 2/1R | 2/2 | 3/1R | 3/2R | 3/3 | TOTAL |
| PSA | 2 | 5 | - | 1 | - | - | 8 |
| RCS | 1 | 7 | - | 3 | - | 6 | 17 |
| TCS | - | 5 | - | 2 | - | 4 | 11 |
| WRS | - | 9 | - | 4 | 4 | 9 | 26 |
| TOTAL | 3 | 26 | - | 10 | 4 | 19 | 62 |

Of the 62 failure modes analyzed, 32 failures were determined to be PCIs. A summary of the PCIs is presented in Table II. Appendix D presents a cross reference between each PCI and a specific worksheet in Appendix C.

| TABLE II Summary of IOA Potential Critical Items | | | | | |
|--|-----|------|-----|------|-------|
| Criticality: | 1/1 | 2/1R | 2/2 | 3/1R | TOTAL |
| EPG/FPC | 3 | 26 | - | - | 32 |

4.1 Analysis Results PSA

The Power Section Assembly consists of the end cell heater/insulator plates, pressure plates, tie rods, individual cell voltage harness, cell performance monitor, and separator plates. These components are illustrated in Figure 4. There

were eight failure modes identified for this division. Of these eight, two are criticality 1/1, five are criticality 2/1R, and one is criticality 3/1R. Seven failures from the PSA are identified to be PCI's. These are listed in Appendix D.

4.2 Analysis Results RCS

The Reactant Control Subsystem consists of preheaters, coupled reactant regulator, hydrogen pump spearator, condenser, hydrogen/water purge vent line and oxygen purge/vent line. These components are illustrated in Figure 5. There were seventeen failure modes identified for the RCS division. Of these seventeen, one is criticality 1/1, seven are criticality 2/1R, three are criticality 3/1R, and six are criticality 3/3. Eight failures from the RCS are identified to be PCI's. These are listed in Appendix D.

4.3 Analysis Results TCS

The Thermal Control Subsystem contains a coolant pump, thermal control valve, coolant accumulator, start/sustaining heater and condenser. These components are illustrated in Figure 8. There were eleven failure modes identified for the TCS division. Of these eleven, five are criticality 2/1R, two are criticality 3/1R, and four are 3/3. Five failures from the TCS are identified to be PCI's. These are listed in Appendix D.

4.4 Analysis Results WRS

The Water Removal Subsystem consists of a condenser, hydrogen pump-separator, water trap and water discharge line. These components are illustrated in Figure 9. There were twenty-six failure modes identified for the WRS division. Of these twenty-six, nine are criticality 2/1R, four are criticality 3/1R, four are criticality 3/2R, and nine are criticality 3/3. Twelve failures from the WRS are identified to be PCI's. These are listed in Appendix D.

5.0 REFERENCES

Reference documentation available from NASA, Rockwell, International, International Fuel Cells, and Pratt and Whitney was used in the analysis. The documentation used included the following:

1. JSC-12820, PCN-1 STS Operational Flight Rules, 12-16-85
2. V45 File III, Operations and Maintenance Requirements and Specification Document - Orbiter OMRSD - Electrical Power Generation/Power Reactant Storage and Distribution, 5-29-86
3. TD268, Shuttle Flight Operations Manual, Vol 2, EPS, 11-84
4. JSC-12830, EGIL Console Procedure Handbook, Rev. C, 10-83
5. NSTS 22206, Instructions for Preparation of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL), 10 October 1986
6. 100-2G, Rockwell International Reliability Desk Instruction Flight Hardware FMEA and CIL, 1-31-84
7. Orbiter Fuel Cell Powerplant Review and Training Course, International Fuel Cells (IFC), 5-86
8. JSC-18691, Flight Data File Malfunction Procedures, Rev. B, 10-10-85
9. JSC-18540, Flight Data File Entry Checklist, Rev. B, 3-17-86
10. JSC-18547, Flight Data File Ascent checklist, Rev. B, 5-28-85
11. JSC-18541, Flight Data File Orbit Operations Checklist, Rev. B, 5-22-85
12. M4001002, JSC Orbiter Full Problem Record Report, EPG Subsystem, 7-22-86.
13. VS70-945099, Integrated System Schematic Electrical Power System (EPS) Orbiter Vehicles -099, 103, 104, 7-18-85
14. VS70-945102, Integrated System Schematic Orbiter OV-102 EPS, 9-19-84
15. Magnesium Plate Status Review and Proposed Investigations to Improve Reliability, IFC, 7-15-86

16. EPA Ban on Future Use of Asbestos Creates Serious Orbiter Fuel Cell Availability Problem, IFC, 7-16-86
17. Orbiter Fuel Cell Powerplant Improved Coolant Accumulator, IFC, 7-15-86
18. Orbiter Fuel Cell Powerplant Improved Cell Performance Monitoring, IFC, 7-15-86
19. Review of IFC Product Improvement Recommendations and Problems and Concerns, (Orbiter Operational Program), IFC, 7-16-86
20. N2 Diagnostic Test Data Review (Comparison of CPM Data to Single Cell Data), IFC, 7-16-86
21. Program Review Orbiter Operational Improvement Program, IFC, 7-15-86
22. Operational Program Powerplant(s) Failure Review, IFC, 7-15-86
23. Rockwell Specifications for Fuel Cells

| | |
|--------------------------|--|
| a. MC 464-0115 | Fuel Cell |
| b. ME 363-0042-0003 | Water Nozzle & Heater Assembly |
| c. MC 284-0431-0001 | Water Pressure Relief Valve |
| d. ME 284-0475-0001 | Water Supply Check Valve |
| e. MC 363-0037-0001 | Strip Heater EPG |
| f. MC 363-0038-0014 | Line Heater H20 Relief Vent Line |
| g. MC 363-0038-0001-0004 | Line Heater Oxygen Purge Line |
| h. MC 363-0038-0003-0004 | Line Heater Hydrogen Purge Line |
| i. MC 363-0037-0002 | Strip Heater Hydrogen Purge Port |
| j. MC 363-0038-0006 | Line Heater, FCP Product Water Line |
| k. ME 449-0160-0003 | Temperature Sensors for Product Water Line, Water Relief Valve, Coolant Return, Oxygen Vent Line, Hydrogen Vent Line and Water Relief Line |
24. Rockwell International Drawings
 - a. VS70-450-102 Orbiter Fuel Cell Control Subsystem
 - b. VS70-450-109 Orbiter Fuel Cell Control Subsystem
 - c. VS70-450-112 Orbiter Fuel Cell Control Subsystem
 - d. VS70-450-119 Orbiter Fuel Cell Control Subsystem
 - e. V070-454-765 Panel - Water Relief Assembly

25. Pratt and Whitney Aircraft Drawings

- a. 752153 Plate - Fuel Electrode
- b. 752154 Plate - Oxidizer Electrode
- c. 752158 Plate - Oxidizer Electrode
- d. 754930 Electrode - Fuel Cell Assembly
- e. 755422 Plate - Fuel Electrode Terminal
- f. 768429 Heater Coolant Start-up
- g. 769016 Regulator, Reactant
- h. 769288 Accumulator and Strap Coolant Assembly
- i. 769546 Filter Coolant (Ref Drawing 14336 501 Change B)
- j. 770488 Transducer - Oxidizer Flow
- k. 770489-91 Transducer - Fuel Flow
- l. 770598-99 Components Assembly - Fuel Cell
- m. 782900 Power Plant Assembly - Fuel Cell
- n. 787900 Power Plant Assembly - Fuel Cell
- o. 788400 Power Plant Assembly - Fuel Cell
- p. 796798 Components Assembly - Fuel Cell
- q. 800634 Cable - Fuel Cell Output Assembly
- r. 800635 Wiring Harness, Fuel Cell Input
- s. 800636 Wiring Harness, Fuel Cell
- t. 822998 Cable Routing - Component Assembly
- u. 823098 Component Assembly - Fuel Cell
- v. 823100 Power Plant Assembly - Fuel Cell

APPENDIX A
ACRONYMS

| | | |
|-------|---|--|
| AOA | - | Abort Once Around |
| ATO | - | Abort To Orbit |
| CIL | - | Critical Items List |
| CPM | - | Cell Performance Monitor |
| CRIT | - | Criticality |
| CSA | - | Cell Stack Assembly |
| C&W | - | Caution and Warning System |
| ECLSS | - | Environmental Control and Life Support System |
| EPA | - | Environmental Protection Agency |
| EPG | - | Electrical Power Generation |
| EPS | - | Electrical Power System |
| F | - | Functional |
| FC | - | Fuel Cell |
| FCP | - | Fuel Cell Powerplant |
| FMEA | - | Failure Mode and Effect Analysis |
| FSSR | - | Flight System Software Requirement |
| GFE | - | Government Furnished Equipment |
| HW | - | Hardware |
| IFC | - | International Fuel Cells |
| IOA | - | Independent Orbiter Assessment |
| MDAC | - | McDonnell Douglas Astronautics Company |
| NASA | - | National Aeronautics and Space Administration |
| NSTS | - | National Space Transportation System |
| NA | - | Not Applicable |
| OMRSD | - | Operations and Maintenance Requirements and Specification Document |
| PCI | - | Potential Critical Item |
| PRCB | - | Program Requirements Control Board |
| PRSDS | - | Power Reactant Storage & Distribution System |
| PSA | - | Power Section Assembly |
| RCS | - | Reactant Control Subsystem |
| RI | - | Rockwell International |
| RTLS | - | Return To Landing Site |
| SM | - | System Management |
| STS | - | Space Transportation System |
| TAL | - | Transatlantic Abort Landing |
| TCS | - | Thermal Control Subsystem |
| UEA | - | Unitized Electrode Assembly |
| WRS | - | Water Removal Subsystem |

APPENDIX B

DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

- B.1 Definitions
- B.2 Project Level Ground Rules and Assumptions
- B.3 Subsystem-Specific Ground Rules and Assumptions

APPENDIX B
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.1 Definitions

Definitions contained in NSTS 22206, Instructions For Preparation of FMEA/CIL, 10 October 1986, were used with the following amplifications and additions.

INTACT ABORT DEFINITIONS:

RTLS - begins at transition to OPS 6 and ends at transition to OPS 9, post-flight

TAL - begins at declaration of the abort and ends at transition to OPS 9, post-flight

AOA - begins at declaration of the abort and ends at transition to OPS 9, post-flight

ATO - begins at declaration of the abort and ends at transition to OPS 9, post-flight

CREDIBLE (CAUSE) - an event that can be predicted or expected in anticipated operational environmental conditions. Excludes an event where multiple failures must first occur to result in environmental extremes

CONTINGENCY CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

EARLY MISSION TERMINATION - termination of onorbit phase prior to planned end of mission

EFFECTS/RATIONALE - description of the case which generated the highest criticality

HIGHEST CRITICALITY - the highest functional criticality determined in the phase-by-phase analysis

MAJOR MODE (MM) - major sub-mode of software operational sequence (OPS)

MC - Memory Configuration of Primary Avionics Software System (PASS)

MISSION - assigned performance of a specific Orbiter flight with payload/objective accomplishments including orbit phasing and altitude (excludes secondary payloads such as GAS cans, middeck P/L, etc.)

MULTIPLE ORDER FAILURE - describes the failure due to a single cause or event of all units which perform a necessary (critical) function

OFF-NOMINAL CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

OPS - software operational sequence

PRIMARY MISSION OBJECTIVES - worst case primary mission objectives are equal to mission objectives

PHASE DEFINITIONS:

PRELAUNCH PHASE - begins at launch count-down Orbiter power-up and ends at moding to OPS Major Mode 102 (liftoff)

LIFTOFF MISSION PHASE - begins at SRB ignition (MM 102) and ends at transition out of OPS 1 (Synonymous with ASCENT)

ONORBIT PHASE - begins at transition to OPS 2 or OPS 8 and ends at transition out of OPS 2 or OPS 8

DEORBIT PHASE - begins at transition to OPS Major Mode 301 and ends at first main landing gear touchdown

LANDING/SAFING PHASE - begins at first main gear touchdown and ends with the completion of post-landing safing operations

APPENDIX B
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.2 IOA Project Level Ground Rules and Assumptions

The philosophy embodied in NSTS 22206, Instructions for Preparation of FMEA/CIL, 10 October 1986, was employed with the following amplifications and additions.

1. The operational flight software is an accurate implementation of the Flight System Software Requirements (FSSRs).

RATIONALE: Software verification is out-of-scope of this task.

2. After liftoff, any parameter which is monitored by system management (SM) or which drives any part of the Caution and Warning System (C&W) will support passage of Redundancy Screen B for its corresponding hardware item.

RATIONALE: Analysis of on-board parameter availability and/or the actual monitoring by the crew is beyond the scope of this task.

3. Any data employed with flight software is assumed to be functional for the specific vehicle and specific mission being flown.

RATIONALE: Mission data verification is out-of-scope of this task.

4. All hardware (including firmware) is manufactured and assembled to the design specifications/drawings.

RATIONALE: Acceptance and verification testing is designed to detect and identify problems before the item is approved for use.

5. All Flight Data File crew procedures will be assumed performed as written, and will not include human error in their performance.

RATIONALE: Failures caused by human operational error are out-of-scope of this task.

6. All hardware analyses will, as a minimum, be performed at the level of analysis existent within NASA/Prime Contractor Orbiter FMEA/CILs, and will be permitted to go to greater hardware detail levels but not lesser.

RATIONALE: Comparison of IOA analysis results with other analyses requires that both analyses be performed to a comparable level of detail.

7. Verification that a telemetry parameter is actually monitored during AOS by ground-based personnel is not required.

RATIONALE: Analysis of mission-dependent telemetry availability and/or the actual monitoring of applicable data by ground-based personnel is beyond the scope of this task.

8. The determination of criticalities per phase is based on the worst case effect of a failure for the phase being analyzed. The failure can occur in the phase being analyzed or in any previous phase, whichever produces the worst case effects for the phase of interest.

RATIONALE: Assigning phase criticalities ensures a thorough and complete analysis.

9. Analysis of wire harnesses, cables, and electrical connectors to determine if FMEAs are warranted will not be performed nor FMEAs assessed.

RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

10. Analysis of welds or brazed joints that cannot be inspected will not be performed nor FMEAs assessed.

RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

11. Emergency system or hardware will include burst discs and will exclude the EMU Secondary Oxygen Pack (SOP), pressure relief valves and the landing gear pyrotechnics.

RATIONALE: Clarify definition of emergency systems to ensure consistency throughout IOA project.

APPENDIX B
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.3 EPG-Specific Ground Rules and Assumptions

1. Component age life will not be considered in the analysis.

RATIONALE: Component age life analysis is beyond the scope of this task.

2. Cryogenic system pressure to the fuel cell will be assumed lost if unable to maintain minimum supply conditions of 100 PSI for H₂ and/or O₂ tanks.

RATIONALE: Minimum requirements definition. Flight rule definition.

3. An O₂ cryo tank will be assumed lost if both of its heaters fail to function (i.e., neither heater will function with the delta current sensors enabled).

RATIONALE: Systems failure definition. Flight rule definition.

4. An H₂ cryo tank will be assumed lost if neither of its heaters will function.

RATIONALE: Systems failure definition. Flight rule definition.

5. An impending loss of all cryo O₂ or all cryo H₂ tanks will be cause to exercise the highest-priority abort mode the loss/leak will allow.

RATIONALE: Flight rule definition.

6. Continue nominal ascent if 2/3/4 O₂ (H₂) tanks fail when flying 3/4/5.

Enter next PLS daily go/no-go if two O₂ (H₂) tanks fail during lift-off and on-orbit.

RATIONALE: Flight rules go/no-go criteria.

7. Ascent abort decision will be needed for any EPG/PRSD/FCP problems that will not support four hours on-orbit plus entry time.

RATIONALE: Flight operations rules.

8. A fuel cell will be considered failed if the following conditions exist.
 - a. An abnormal or unexplained voltage versus current performance loss of >0.5 volts for a single FC based on predicted performance data.
 - b. Coolant pump or H₂ pump/H₂O separator is lost.
 - c. Fuel cell stack-coolant temperature >255 degrees (242.5) degrees F or <175 degrees (182.5) degrees F.
 - d. Coolant pressure >75 (71.4) PSIA and increasing.
 - e. Fuel cell unable to discharge water to the ECLSS H₂O storage tanks or overboard via the fuel cell H₂O relief system.
 - f. Local KOH concentration >48 percent (45 percent) dry or <24 percent (29 percent) wet as indicated by fuel cell stack-coolant temperature, condenser exit temperature, and current relationship.
 - g. Fuel cell reactant valve fails closed.
 - h. Cannot be connected to a main bus.
 - i. Fuel cell H₂O pH high confirmed.
 - j. Fuel cell O₂ reaction chambers cannot be purged.
 - k. Fuel cell end-cell heater failing on.
 - l. Fuel cell substack delta volts >150 millivolts and increasing.

RATIONALE: Systems failure definition.

9. Loss of one fuel cell is considered cause for priority flight and abort decision.

RATIONALE: Mission flight rule definition.

10. Loss of two fuel cells is considered cause for abort mission.

RATIONALE: Contingency action summary. Flight Rule definition.

11. Loss of three fuel cells is considered loss of life/vehicle in all mission phases.

RATIONALE: Flight rule definition.

12. Loss of two fuel cells in the first stage of ascent is considered loss of life/vehicle.

RATIONALE: SRB loads are too high for one fuel cell to support. Voltage may go <25v which will shut down the GPCs.

13. Although the ECLSS product-water storage is a separate system from EPG, it will be considered as a failable redundant product-water relief line for purposes of the EPG functional criticality scenarios.

RATIONALE: This assumption violates general ground rule 3.1.1.6 but is essential for evaluating failures associated with the water relief line.

14. Filter failure will only be considered in the case of total flow blockage. Cases of improper/insufficient filtering will not be considered except where obvious.

RATIONALE: The effect of 'poor' filter performance on downstream components is beyond the scope of our efforts.

15. The start/sustaining heater on the left-hand FCP (FCP #1) is assumed to be disconnected. Thus, this FCP cannot be maintained operational at no-load, and will be considered shutdown if the load cannot be maintained at greater than 2 KW.

RATIONALE: Load needed to maintain operating temperature. Right hand FCP uses sustaining heater to maintain temperature at no-load.

16. For all "failed open" failure modes for valves which are normally open, redundancy screen B will be assumed failed.

RATIONALE: The failure is not detectable until the valve is required to be closed.

17. Five O2 and H2 tanks are being used as the baseline configuration under study.

RATIONALE: The configuration for all redundant components is being considered for this analysis.

18. Inadvertant Fuel Cell shutdown during RTLS and TAL abort is considered loss of crew/vehicle.

RATIONALE: Loss of FCP 1/Bus A is loss of OMS Engine Purge Capability (required for TAL) and Aft Compartment MPS Helium Purge Capability (required for RTLS and TAL).



APPENDIX C DETAILED ANALYSIS

This section contains the IOA analysis worksheets generated during the analysis of this subsystem. The information on these worksheets is intentionally similar to the NASA FMEAs. Each of these sheets identifies the hardware item being analyzed, and parent assembly, as well as the function. For each failure mode, the possible causes are outlined, and the assessed hardware and functional criticality for each mission phase is listed, as described in the NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. Finally, effects are entered at the bottom of each sheet, and the worst case criticality is entered at the top.

LEGEND FOR IOA ANALYSIS WORKSHEETS

Hardware Criticalities:

- 1 = Loss of life or vehicle
- 2 = Loss of mission or next failure of any redundant item (like or unlike) could cause loss of life/vehicle
- 3 = All others

Functional Criticalities:

- 1R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of life or vehicle.
- 2R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of mission.

Redundancy Screen A:

- 1 = Is Checked Out PreFlight
- 2 = Is Capable of Check Out PreFlight
- 3 = Not Capable of Check Out PreFlight
- NA = Not Applicable

Redundancy Screens B and C:

- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 101 ABORT: 1/1

ITEM: FUEL CELL
FAILURE MODE: LOSS ELECTRICAL CONTACT IN THE POWER SECTION

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 1/1 |
| LIFTOFF: | 2/1R | TAL: | 1/1 |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CORROSION, THERMAL STRESS,
FATIGUE

EFFECTS/RATIONALE:
LOSS OF ELECTRICAL CONTACT CAUSES INADVERTANT FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 104 ABORT: 2/1R

ITEM: END CELL HEATER
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: ELECTRICAL FAILURE

EFFECTS/RATIONALE:

LOSS OF FUEL CELL THERMAL INSULATION IS CAUSED BY THE FAILED OFF END CELL HEATERS. DURING LIGHT ELECTRICAL LOADING OF THE FUEL CELL, THE LOSS OF THE FUEL CELL HEATER MAY CAUSE CELL FLOODING WHICH REQUIRES FCP SHUTDOWN. ELECTRICAL END CELL HEATERS ARE BEING REPLACED WITH HEATERS CONTROLLED BY THE COOLANT SYSTEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 105

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 2/1R
ABORT: 2/1R

ITEM: END CELL HEATER
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: ELECTRICAL FAILURES

EFFECTS/RATIONALE:

ON ORBIT THE FUEL CELL WOULD HAVE TO BE SHUTDOWN WITH A FAILED END CELL HEATER. EXCESSIVE HEATING WILL DEGRADE CELL MATRIX OR SEALS AND ALLOW REACTANT CROSSOVER.

WITH THE END CELL HEATERS FAILED ON THE FUEL CELL CAN OPERATE FOR 51 MINUTES BEFORE THE CELL HAS TO BE SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 1/1
MDAC ID: 106 ABORT: 1/1

ITEM: SEPARATOR PLATES/UEA
FAILURE MODE: REACTANT LEAKAGE TO ORBITER (EXTERNAL LEAKAGE)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 1/1 | RTLS: | 1/1 |
| LIFTOFF: | 1/1 | TAL: | 1/1 |
| ONORBIT: | 1/1 | AOA: | 1/1 |
| DEORBIT: | 1/1 | ATO: | 1/1 |
| LANDING/SAFING: | 1/1 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: SEAL FAILURE

EFFECTS/RATIONALE:

AN EXTERNAL REACTANT LEAK IN THE SEPARATOR PLATES CAN CAUSE A POTENTIAL EXPLOSION/FIRE. THE LEAKAGE IS DETECTABLE WITH HIGH REACTANT FLOW RATES.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 1/1
MDAC ID: 107 ABORT: 1/1

ITEM: SEPARATOR PLATES/UEA
FAILURE MODE: INTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 1/1 | RTLS: | 1/1 |
| LIFTOFF: | 1/1 | TAL: | 1/1 |
| ONORBIT: | 1/1 | AOA: | 1/1 |
| DEORBIT: | 1/1 | ATO: | 1/1 |
| LANDING/SAFING: | 1/1 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: DEFECT IN ELECTROLYTE MATIRX; DEFECT IN SEAL/SEPARATOR PLATE; EXCESSIVE REACTANT PRESSURE

EFFECTS/RATIONALE:

REACTANT CROSSOVER WITHIN THE SEPARATOR PLATES CAN CAUSE POTENTIAL EXPLOSION/FIRE HAZARD. THE REACTANT CROSSOVER IS DETECTABLE BY CELL PERFORMANCE MONITOR AND HIGH REACTANT FLOW RATES.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 108 ABORT: 2/1R

ITEM: SEPARATOR PLATES
FAILURE MODE: COOLANT LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: SEAL FAILURE

EFFECTS/RATIONALE:

COOLANT LEAK WITHIN THE SEPARATOR PLATES WILL CONTAMINATE THE ELECTROLYTE AND DEGRADE FCP PERFORMANCE. IT COULD ALSO CAUSE LOSS OF TEMPERATURE CONTROL. EITHER CONDITION WILL REQUIRE FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 109 ABORT: 2/1R

ITEM: SEPARATOR PLATES
FAILURE MODE: REACTANT BLOCKAGE (O2 INLET MANIFOLD)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CORROSION, CONTAMINATION

EFFECTS/RATIONALE:

IF THE OXYGEN INLET TO THE SEPARATOR PLATE IS BLOCKED, THEN HIGH HYDROGEN CONCENTRATION FORCES ELECTROLYTE OUT OF THE CELL MATRIX RESULTING IN PRODUCT WATER CONTAMINATION AND FCP DEGRADATION. WATER CONTAMINATION IS GROUND RULE FOR FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 110 ABORT: 3/1R

ITEM: CELL PERFORMANCE MONITOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) PSA
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0015

CAUSES: ELECTRICAL FAILURE

EFFECTS/RATIONALE:

ERRONEOUS OUTPUT WOULD CAUSE LOSS OF ABILITY TO MONITOR CELL PERFORMANCE AND CELL FAILURE. IF THE CPM IS LOST FOR ONE FUEL CELL, THE AFFECTED CELL CAN BE BUS TIED FOR PERFORMANCE MONITORING. IF ALL CPM'S ARE LOST, IT COULD BE CATASTROPHIC. REACTANT CROSSOVER, WHICH COULD RESULT IN AN EXPLOSION, WOULD BE UNDETECTABLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 111 ABORT: 1/1

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: GROSS VENTING

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 1/1 |
| LIFTOFF: | 2/1R | TAL: | 1/1 |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, FATIGUE, CORROSION,
CONTAMINATION

EFFECTS/RATIONALE:

GROSS VENTING ALLOWS REACTANTS TO VENT THROUGH THE PURGE/VENT
LINE AT A FLOW RATE THAT PREVENTS REACTANT FLOW TO THE PSA. THIS
WOULD CAUSE INADVERTANT FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 112 ABORT: 2/1R

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: H2 OVERPRESSURE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CORROSION, CONTAMINATION,
PIECE PART STRUCTURAL FAILURE.

EFFECTS/RATIONALE:

HYDROGEN OVERPRESSURE WILL CAUSE ELECTROLYTE DEPLETION, WATER
CONTAMINATION AND CELL SEAL FAILURE. HYDROGEN OVERPRESSURIZATION
WOULD BE CAUSE FOR FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 113 ABORT: 1/1

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: H2 STARVATION

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 1/1 |
| LIFTOFF: | 2/1R | TAL: | 1/1 |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CORROSION, CONTAMINATION,
PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:
HYDROGEN STARVATION CAUSES INADVERTANT FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 114 ABORT: 2/1R

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: O2 OVERPRESSURE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CONTAMINATION, CORROSION,
PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:

OXYGEN OVERPRESSURIZATION WILL CAUSE SEAL FAILURE AND OXYGEN
LEAKAGE AND COOLANT OVERPRESSURE (THROUGH ACCUMULATOR). OXYGEN
OVERPRESSURIZATION WOULD BE CAUSE FOR FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 115 ABORT: 1/1

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: O2 STARVATION

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 1/1 |
| LIFTOFF: | 2/1R | TAL: | 1/1 |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CONTAMINATION, CORROSION,
PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:

OXYGEN STARVATION WILL CAUSE ELECTROLYTE DEPLETION WATER
CONTAMINATION, AND SEAL FAILURE. REACTANT STARVATION CAUSES
INADVERTANT FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 116 ABORT: 2/1R

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: PURGE FAILURE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: ELECTRICAL FAILURE, MECHANICAL SHOCK, VIBRATION, CONTAMINATION, CORROSION, PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:

PURGE FAILURE OF THE INTEGRATED DUAL GAS REGULATOR WILL DEGRADE THE FUEL CELL PERFORMANCE. AN ADDITIONAL FAILURE RESULTING IN THE NEED TO VENT WOULD CAUSE REACTANT OVERPRESSURE, WHICH REQUIRES FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 1/1
MDAC ID: 117 ABORT: 1/1

ITEM: H2/O2 LINES AND FITTINGS AND ACCESSORY COMPONENTS
FAILURE MODE: REACTANT LEAKAGE TO THE ORBITER (EXTERNAL LEAKAGE)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 1/1 | RTLS: | 1/1 |
| LIFTOFF: | 1/1 | TAL: | 1/1 |
| ONORBIT: | 1/1 | AOA: | 1/1 |
| DEORBIT: | 1/1 | ATO: | 1/1 |
| LANDING/SAFING: | 1/1 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION, CONTAMINATION,
PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:

AN EXTERNAL REACTANT LEAK AT THE COMPONENT CAN CAUSE A POTENTIAL
EXPLOSION/FIRE. THE LEAKAGE IS DETECTABLE BY HIGH REACTANT FLOW
RATES.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 118 ABORT: 2/1R

ITEM: O2/H2 PURGE-VENT LINES AND VENT NOZZLES
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: V070-454720-003, V070-454720-004, V070-454210, V070-454211

CAUSES: CONTAMINATION, FREEZING

EFFECTS/RATIONALE:

RESTRICTED FLOW WITHIN THE VENT LINES AND NOZZLES PREVENTS THE PURGE OF THE FUEL CELL POWERPLANTS (FCP). THE INABILITY TO PURGE FCP'S WILL DEGRADE THEIR PERFORMANCE. AN ADDITIONAL FAILURE RESULTING IN THE NEED TO VENT COULD BE CATASTROPHIC. THIS WOULD CAUSE REACTANT OVERPRESSURE. THIS FAILURE WOULD BE DETECTED DURING PURGE ATTEMPTS AND BY H2/O2 FLOWS AND PURGE LINE TEMPERATURE SENSORS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 119 ABORT: 3/3

ITEM: O2 PURGE LINE TEMPERATURE SENSOR
FAILURE MODE: OPEN OR SHORT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED TEMPERATURE SENSOR PREVENTS THE AUTO PURGE SEQUENCE BY INDICATING A CONSTANT LOW SCALE TEMPERATURE. MANUAL PURGE CAN BE PERFORMED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 120 ABORT: 3/3

ITEM: O2 PURGE LINE TEMPERATURE SENSOR
FAILURE MODE: OUT OF TOLERANCE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

IF THE SENSOR INDICATES A HIGH TEMPERATURE, THEN THE PURGE VALVE COULD OPEN BEFORE THE OXYGEN LINE IS HEATED. THEREFORE, THE LINE COULD FREEZE WHICH COULD PREVENT PURGING. THE LOSS OF PURGING COULD CAUSE DEGRADED FUEL CELL PERFORMANCE. USE OF MANUAL HEATERS WOULD ALLEVIATE THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 121 ABORT: 3/3

ITEM: H2 PURGE LINE TEMPERATURE SENSORS 1 & 2
FAILURE MODE: OPEN OR SHORTED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED TEMPERATURE SENSOR PREVENTS THE AUTO PURGE SEQUENCE BY INDICATING A CONSTANT LOW SCALE TEMPERATURE. MANUAL PURGE CAN BE PERFORMED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 122 ABORT: 3/3

ITEM: H2 PURGE LINE TEMP. SENSORS 1 & 2
FAILURE MODE: OUT OF TOLERANCE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

IF THE SENSOR INDICATES A HIGH TEMPERATURE, THEN THE PURGE VALVE COULD OPEN BEFORE THE LINE IS HEATED. THIS COULD CAUSE THE LINE TO FREEZE. A FROZEN LINE COULD PREVENT A PURGE WHICH WOULD CAUSE PERFORMANCE OF THE FUEL CELL TO BE DEGRADED. USE OF MANUAL HEATERS WOULD ALLEVIATE THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 123 ABORT: 3/1R

ITEM: O2 PURGE LINE HEATERS (6)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/1R | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0001, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:

THE FAILURE OF THE GPC HEATER CIRCUITS HAS NO EFFECT ON THE SYSTEM BECAUSE OF REDUNDANT HEATER CIRCUITS. IF BOTH HEATER CIRCUITS FAILED, THE LINE COULD FREEZE AND PURGE CAPABILITY WOULD BE LOST. A FAILURE RESULTING IN THE NEED TO VENT COULD CAUSE OVERPRESSURIZATION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 124 ABORT: 3/3

ITEM: O2 PURGE LINE HEATERS (6)
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0001, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:

A FAILED ON HEATER HAS NO MAJOR EFFECT ON THE FUEL CELL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 125 ABORT: 3/1R

ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/1R | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0003, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:

THE FAILURE OF THE GPC HEATER CIRCUITS HAS NO EFFECT ON THE FUEL CELL BECAUSE OF REDUNDANT HEATERS. IF BOTH HEATER CIRCUITS FAIL, THE LINE COULD FREEZE AND PURGE CAPABILITY WOULD BE LOST. A FAILURE RESULTING IN THE NEED TO VENT COULD CAUSE OVERPRESSURIZATION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 126 ABORT: 3/3

ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0003, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:

A FAILED ON HEATER HAS NO MAJOR EFFECT ON THE FUEL CELL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 127 ABORT: 3/1R

ITEM: O2/H2 FLOWMETER
FAILURE MODE: ZERO OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) RCS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

IF A FLOWMETER MALFUNCTIONS, THEN LEAKING REACTANT WOULD BE UNDETECTABLE WHICH COULD POSSIBLY BE CATASTROPHIC.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 128 ABORT: 3/3

ITEM: START-UP HEATER
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

THE START/SUSTAINING HEATERS HAVE BEEN DISCONNECTED ON FCP1.
FUEL CELL START-UP PROCESS WOULD TAKE LONGER AND WOULD POSSIBLY
HAVE DEGRADED FUEL CELL PERFORMANCE DUE TO LOSS OF SUSTAINING
HEATER THAT MAINTAINS COOLANT TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 129 ABORT: 2/1R

ITEM: START-UP HEATER
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

IF THE HEATER FAILS ON, THE FUEL CELL WOULD OVERHEAT WHICH COULD CAUSE EXCESSIVE KOH RELEASE AND ELECTROLYTE DRYOUT. ELECTROLYTE DRYOUT CAN LEAD TO CROSSOVER AND REQUIRES FCP SHUTDOWN. THE HEAT COULD CAUSE COOLANT TO DRYOUT OR CHAR. THIS COULD POSSIBLY LEAD TO COOLANT PUMP FAILURE DUE TO PLUGGING FROM COOLANT CHARRING BY-PRODUCT. THIS WOULD ALSO REQUIRE FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 130 ABORT: 2/1R

ITEM: H2/02 PREHEATER
FAILURE MODE: RESTRICTED COOLANT FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK

EFFECTS/RATIONALE:

LOSS OF COOLANT FLOW TO THE FCP WOULD REQUIRE THE FUEL CELL TO BE SHUTDOWN. THIS WOULD BE DETECTED BY THE COOLANT DELTA PRESSURE SWITCH.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 131 ABORT: 2/1R

ITEM: H2/02 PREHEATER, PUMP, THERMAL CONTROL VALVE,
CONDENSER, FILTERS, START/SUSTAIN HEATER, ACCUMULATOR, FLEXIBLE
INTERFACES, ECLSS HEAT EXCHANGERS
FAILURE MODE: EXTERNAL LEAK OF TCS COOLANT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK

EFFECTS/RATIONALE:

EXTERNAL LEAKAGE CAUSES A DECREASE IN COOLANT PRESSURE OF THE SYSTEM AND LOSS OF COOLANT FLOW TO THE FCP. THIS IS DETECTABLE BY THE COOLANT DELTA PRESSURE SWITCH. LOSS OF COOLANT WILL CAUSE FCP OVERHEATING AND POSSIBLE REACTANT CROSSOVER. THIS REQUIRES FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 132 ABORT: 2/1R

ITEM: COOLANT PUMP
FAILURE MODE: LOSS OF OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CONTAMINATION, VIBRATION, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

COOLANT PUMP FAILURE WILL RESULT IN FCP OVERHEATING DUE TO INSUFFICIENT COOLANT FLOW. THIS MAY RESULT IN ELECTROLYTE DRYOUT WHICH COULD CAUSE REACTANT CROSSOVER. THIS REQUIRES FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 133 ABORT: 3/3

ITEM: COOLANT PRESSURE SWITCH
FAILURE MODE: FAIL OPEN

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: PIECE PART FAILURE, SHOCK, VIBRATION

EFFECTS/RATIONALE:

THE PRESSURE TAB WILL NOT GO GRAY WHEN FUEL CELL START-UP IS PERFORMED OR IT WILL GO TO BARBER POLE, IF THE FCP IS ALREADY RUNNING. RELAY K9 WILL NOT CLOSE, WHICH WILL PREVENT START-UP HEATER FROM ACTIVATING AND THE FLOW CONTROL BY-PASS VALVE FROM ACTIVATING. IF START BUTTON IS RELEASED THE FUEL CELL WILL DO AN AUTOMATIC SHUTDOWN. NOTE: FUEL CELL CAN STILL BE STARTED IF THE START BUTTON IS HELD DOWN FOR AT LEAST 32 SECONDS. THIS ALLOWS ENOUGH TIME FOR THE TIMER MODULE TO CLOSE RELAY K10.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 134 ABORT: 3/3

ITEM: STACK INLET TEMPERATURE SENSOR
FAILURE MODE: FULL OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

DETECTS STACK INLET TEMPERATURE USED BY START-UP HEATER ELECTRONICS. FAILURE HIGH WOULD PREVENT HEATER OPERATION WHICH WOULD SLOW THE START-UP PROCESS. NOTE THAT THE START-UP HEATER IS DISCONNECTED ON FCP#1.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 135 ABORT: 3/1R

ITEM: STACK INLET TEMPERATURE SENSOR
FAILURE MODE: LOW OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

MEASURES THE TEMPERATURE OF COOLANT ENTERING STACK USED BY THE START-UP HEATER ELECTRONICS. FAILURE LOW WOULD LOSE ONE PATH FOR START-UP HEATER SHUTDOWN. REMAINING PATH IS STACK OUTLET TEMPERATURE SENSOR AND ELECTRONICS AND MANUAL SWITCHES. FAILURE OF REDUNDANT PATHS COULD CAUSE START-UP HEATER TO FAIL ON WHICH COULD REQUIRE FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 136 ABORT: 3/3

ITEM: STACK OUTLET TEMPERATURE SENSOR
FAILURE MODE: FULL OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

MEASURES THE TEMPERATURE OF COOLANT EXITING THE STACK WHICH IS USED BY THE START-UP/SUSTAINING HEATER ELECTRONICS. FAILURE HIGH COULD PREVENT START-UP OR SUSTAINING HEATER OPERATION. START-UP HEATER FAILURE COULD SLOW THE FCP START-UP PROCESS. SUSTAINING HEATER FAILURE COULD DEGRADE THE FCP PERFORMANCE.
NOTE: START-UP HEATER IS DISCONNECTED ON FCP#1.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 137 ABORT: 3/1R

ITEM: STACK OUTLET TEMPERATURE SENSOR
FAILURE MODE: LOW OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

MEASURES THE TEMPERATURE OF THE COOLANT EXITING THE STACK WHICH IS USED BY THE START-UP/SUSTAINING HEATER ELECTRONICS. SENSOR FAILURE LOW COULD PREVENT START-UP OR SUSTAINING HEATER SHUTDOWN. THIS WOULD REQUIRE FCP SHUTDOWN. NOTE: START-UP HEATER IS DISCONNECTED ON FCP#1.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 138 ABORT: 2/1R

ITEM: WATER SEPARATOR PUMP
FAILURE MODE: DEGRADED PERFORMANCE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CONTAMINATION, STRUCTURAL PART FAILURE, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED OFF OR DEGRADED PERFORMANCE WATER SEPARATOR PUMP WILL FLOOD A FUEL CELL. THIS RESULTS IN DECREASED ELECTROLYTE CONCENTRATION AND REQUIRES FUEL CELL SHUTDOWN. AN ERRATIC PUMP MOTOR IS DETECTABLE BY ITS VOLTAGE AND CURRENT MEASUREMENTS, BECAUSE OF LIQUID GETTING INTO THE PUMP. A MOTOR FAILURE IS ALSO DETECTABLE BY A PH MEASUREMENT AND HIGH CONDENSER OUTLET TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 139 ABORT: 1/1

ITEM: WATER SEPARATOR PUMP/WATER CONDENSATE TRAP
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 1/1 |
| LIFTOFF: | 2/1R | TAL: | 1/1 |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CONTAMINATION

EFFECTS/RATIONALE:

RESTRICTED HYDROGEN FLOW FROM THE WATER SEPARATOR PUMP CAUSES
REACTANT STARVATION AND INADVERTANT FUEL CELL SHUTDOWN. LOSS OF
A SINGLE FUEL CELL REQUIRES PRIORITY MISSION AND/OR ABORT
DECISION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 141 ABORT: 2/1R

ITEM: THERMAL CONTROL VALVE
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) TCS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY

PART NUMBER: MC464-0115

CAUSES: FATIGUE, MECHANICAL SHOCK, ELECTRICAL FAILURE, BINDING

EFFECTS/RATIONALE:

ERRONEOUS OUTPUT COULD CAUSE ELECTROLYTE DRY OUT. THE CONDENSER WOULD CONDENSE TOO MUCH WATER. THIS CONDITION CAN LEAD TO REACTANT CROSSOVER AND EXPLOSION. IF THE REVERSE FAILURE OCCURS, FUEL CELL FLOODING COULD OCCUR.

COOLANT TEMPERATURE WOULD NOT BE SUFFICIENT FOR CONDENSING WATER. EITHER FAILURE REQUIRES FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 142 ABORT: 2/1R

ITEM: WATER DISCHARGE VALVE
FAILURE MODE: FAIL CLOSED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED CLOSED WATER DISCHARGE VALVE WILL CAUSE FUEL CELL FLOODING FROM WATER BUILD UP. FLOODING OF THE FUEL CELL REQUIRES SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 143 ABORT: 2/1R

ITEM: H2O DISCHARGE LINE
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: CONTAMINATION, CORROSION, FROZEN WATER

EFFECTS/RATIONALE:

RESTRICTED FLOW CAUSES FUEL CELL FLOODING AND SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 144 ABORT: 3/3

ITEM: PH WATER SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

IF THE PH SENSOR FAILS TO WORK, THE PH CAN BE TESTED MANUALLY.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 145 ABORT: 3/3

ITEM: PRODUCT WATER LINE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED TEMPERATURE SENSOR CAUSES LOSS OF MEASUREMENT. A FAILED TEMPERATURE SENSOR CAN BE DETECTED BY SWITCHING TO THE STANDBY HEATERS AND CHECKING THE MEASUREMENT TO SEE IF IT STABILIZES. IF THE MEASUREMENT STABILIZES, THIS WOULD INDICATE THAT A FAILED HEATER WAS CAUSING THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 146 ABORT: 3/3

ITEM: PRODUCT WATER LINE HEATER (A&B)
FAILURE MODE: FAILED ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
FAILED ON LINE HEATERS HAVE NO EFFECT ON THE CREW OR MISSION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 147 ABORT: 3/3

ITEM: PRODUCT WATER LINE HEATER (A&B)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

THE PRODUCT WATER LINE HEATERS ARE USED DURING START-UP. DURING NORMAL MISSIONS, THE HEATERS ARE NOT INITIATED, NOR IS THE FUEL CELL STOPPED AND RESTARTED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 148 ABORT: 2/1R

ITEM: PRODUCT WATER LINE
FAILURE MODE: RESTRICTED FLOW (EXTERNAL LEAKAGE)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 2/1R |
| LIFTOFF: | 2/1R | TAL: | 2/1R |
| ONORBIT: | 2/1R | AOA: | 2/1R |
| DEORBIT: | 2/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: VO70-454110-124

CAUSES: CONTAMINATION, FROZEN

EFFECTS/RATIONALE:

RESTRICTED FLOW WITHIN THE PRODUCT WATER LINE WOULD RESULT IN NO PRODUCT WATER TO THE ECLSS. IF THE WATER RELIEF LINE ALSO BECOMES BLOCKED, THEN ALL OF THE FUEL CELLS WOULD FLOOD. THIS MEANS YOU ARE ONE FAILURE AWAY FROM LOSS OF CREW/VEHICLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/2R
MDAC ID: 149 ABORT: 3/2R

ITEM: WATER SUPPLY CHECK VALVE
FAILURE MODE: EXTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/2R | TAL: | 3/3 |
| ONORBIT: | 3/2R | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/2R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [F]

LOCATION: MID-BODY
PART NUMBER: ME284-0475-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

AN EXTERNAL LEAK AT THE WATER SUPPLY CHECK VALVE CAUSES LOSS OF PRODUCT WATER FROM THE FUEL CELL TO THE ECLSS. LOSS OF ALL PRODUCT WATER MEANS MISSION TERMINATION DUE TO INSUFFICIENT POTABLE WATER. LEAKAGE OF THE CHECK VALVE IN THE WATER RELIEF PANEL ASSEMBLY CAN CAUSE FREEZING OF ALL FUEL CELL WATER LINES. THIS WOULD RESULT IN FLOODING OF ALL FUEL CELLS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 150 ABORT: 3/1R

ITEM: WATER SUPPLY CHECK VALVE
FAILURE MODE: FAIL CLOSED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: ME284-0475-0001

CAUSES: VIBRATION, MECHANICAL SHOCK

EFFECTS/RATIONALE:

FAILURE OF THE CHECK VALVE WOULD NOT BE CRITICAL UNLESS THE RELIEF VALVE ALSO FAILED CLOSED. THIS WOULD CAUSE THE FUEL CELL TO OVERPRESSURE AND FLOOD.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/2R
MDAC ID: 151 ABORT: 3/2R

ITEM: WATER SUPPLY CHECK VALVE
FAILURE MODE: FAILS TO CHECK

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/2R | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/2R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [F] C [P]

LOCATION: MID-BODY
PART NUMBER: ME284-0475-0001

CAUSES: CONTAMINATION, FROZEN

EFFECTS/RATIONALE:

FAILURE OF A SINGLE CHECK VALVE TO CHECK PROPERLY MAY ALLOW ALL FUEL CELLS TO VENT WATER THROUGH A SINGLE WATER RELIEF VALVE. THE FIRST FAILURE WOULD BE A WATER RELIEF VALVE FAILED OPEN. THE SECOND FAILURE WOULD BE THE CHECK VALVE FOR THE SAME FUEL CELL FAILING TO CHECK. THIS COULD CAUSE MISSION TERMINATION DUE TO LOSS OF ALL POTABLE WATER.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/2R
MDAC ID: 152 ABORT: 3/2R

ITEM: WATER RELIEF VALVE
FAILURE MODE: EXTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/2R | TAL: | 3/3 |
| ONORBIT: | 3/2R | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/2R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [F]

LOCATION: MID-BODY
PART NUMBER: MC284-0431-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

AN EXTERNAL LEAK AT THE WATER RELIEF VALVE CAUSES LOSS OF PRODUCT WATER FROM THE FUEL CELL TO THE ECLSS. LOSS OF ALL PRODUCT WATER MEANS MISSION TERMINATION DUE TO INSUFFICIENT POTABLE WATER. LEAKAGE OF THE RELIEF VALVE IN THE WATER RELIEF PANEL ASSEMBLY CAN CAUSE FREEZING OF ALL FUEL CELL WATER LINES. THIS WOULD RESULT IN FLOODING OF ALL FUEL CELLS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/2R
MDAC ID: 153 ABORT: 3/2R

ITEM: WATER RELIEF VALVE
FAILURE MODE: FAILS OPEN

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/2R | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/2R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC284-0431-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED OPEN WATER RELIEF VALVE CAUSES LOSS OF THE PRODUCT WATER FROM THE ONE FUEL CELL TO THE ECLSS. LOSS OF ALL PRODUCT WATER COULD OCCUR WITH A SECOND FAILURE: THE WATER RELIEF CHECK VALVE STUCK OPEN (FAILS TO CHECK) COULD ALLOW ALL PRODUCT WATER FROM ALL FCP'S TO VENT THROUGH THE SINGLE OPEN VALVE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 154 ABORT: 3/1R

ITEM: WATER RELIEF VALVE
FAILURE MODE: FAILS CLOSED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [NA] C [P]

LOCATION: MID-BODY
PART NUMBER: MC284-0431-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

LOSS OF RELIEF VALVE CAUSES NO MAJOR IMPACT, BUT IF A BLOCKAGE OCCURS WITHIN THE ECLSS PRODUCT WATER LINE, THEN FUEL CELL WOULD FLOOD WHICH IS A GROUND RULE FOR FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 155 ABORT: 3/1R

ITEM: WATER RELIEF VALVE HEATER (A&B)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

FAILED OFF HEATERS COULD CAUSE WATER TO FREEZE IN VALVE AND BLOCK THE RELIEF LINE. THIS FAILURE COULD CAUSE LOSS OF A FCP, IF THE WATER NEEDS TO BE VENTED. REDUNDANT HEATERS MUST FAIL FOR THIS TO OCCUR.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 156 ABORT: 3/3

ITEM: WATER RELIEF VALVE HEATER A&B
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

FAILED ON HEATERS HAVE NO EFFECT ON THE FUEL CELL OR
MISSION/CREW.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 157 ABORT: 3/3

ITEM: WATER RELIEF VALVE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED TEMPERATURE SENSOR CAUSES LOSS OF MEASUREMENT. A FAILED TEMPERATURE SENSOR CAN BE DETECTED BY SWITCHING TO THE STANDBY HEATERS AND CHECKING THE MEASUREMENT TO SEE IF IT STABILIZES. IF THE MEASUREMENT STABILIZES, THIS WOULD INDICATE THAT A FAILED HEATER WAS CAUSING THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 158 ABORT: 3/3

ITEM: WATER RELIEF LINE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

A FAILED TEMPERATURE SENSOR IS LOSS OF MEASUREMENT ONLY. (THE LINE HEATERS ARE CONTROLLED BY THERMOSTATS.) INSTRUMENT LOSS CAN BE CHECKED BY SWITCHING TO A REDUNDANT HEATER TO SEE IF THAT STABILIZES THE LINE TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 159 ABORT: 2/1R

ITEM: WATER RELIEF (VENT) LINE
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 2/1R |
| LIFTOFF: | 2/1R | TAL: | 2/1R |
| ONORBIT: | 2/1R | AOA: | 2/1R |
| DEORBIT: | 2/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [NA] C [P]

LOCATION: MID-BODY
PART NUMBER: V070-454110

CAUSES: CONTAMINATION, FREEZE-UP

EFFECTS/RATIONALE:

RESTRICTED FLOW WITHIN THE WATER RELIEF (VENT) LINE WOULD LOSE THE RELIEF FUNCTION FOR ALL CELLS. ADDITIONALLY, IF THE PRODUCT WATER LINE PLUGGED UP, THEN ALL THE FUEL CELLS WOULD FLOOD. THUS, WITH THE WATER RELIEF LINE PLUGGED, THERE IS ONLY ONE PATH (PRODUCT WATER LINE) REMAINING BEFORE LOSS OF LIFE/VEHICLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/1R
MDAC ID: 160 ABORT: 3/1R

ITEM: WATER VENT LINE HEATER A&B AND BARREL HEATER A&B
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/1R | TAL: | 3/1R |
| ONORBIT: | 3/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 3/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, MECHANICAL SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

THE FIRST HEATER LOSS HAS NO EFFECT ON THE WATER VENT LINE BECAUSE OF REDUNDANT HEATERS. THE LOSS OF REDUNDANT HEATERS MAY CAUSE THE VENT LINE TO FREEZE. THIS FAILURE WOULD NOT BE A PROBLEM UNLESS THE ECLSS LINE IS ALSO BLOCKED, WHICH CAN CAUSE FUEL CELL FLOODING.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 161 ABORT: 3/3

ITEM: WATER VENT LINE HEATER A&B AND BARREL HEATER A&B
FAILURE MODE: FAILED ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
FAILED ON HEATERS HAVE NO EFFECT ON THE CREW OR MISSION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 162 ABORT: 3/3

ITEM: WATER NOZZLE HEATER (A&B)
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME363-0042-0003

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

NOZZLE HEATER A IS DISCONNECTED, THEREFORE, THE HEATER ELEMENT IS NOT REDUNDANT. A FAILED ON NOZZLE HEATER HAS NO EFFECT ON THE FUEL CELL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 163 ABORT: 2/1R

ITEM: WATER NOZZLE HEATER (A&B)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|-----------------|----------|-------|----------|
| PRELAUNCH: | 3/3 | RTLS: | 2/1R |
| LIFTOFF: | 2/1R | TAL: | 2/1R |
| ONORBIT: | 2/1R | AOA: | 2/1R |
| DEORBIT: | 2/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: ME363-0042-0003

CAUSES: VIBRATION, MECHANICAL SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

IF THE WATER IN THE NOZZLE FREEZES, THE WATER RELIEF FUNCTION IS LOST. ADDITIONALLY, IF THE PRODUCT WATER LINE IS BLOCKED, ALL THE FUEL CELLS WILL FLOOD. NOZZLE HEATER A IS DISCONNECTED; THEREFORE, THE HEATER ELEMENT IS NOT REDUNDANT. HOWEVER, FOR THE NEXT FLIGHT THE HEATER WILL BE FUNCTIONAL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 164

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 2/1R
ABORT: 2/1R

ITEM: WATER RELIEF NOZZLE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 2/1R | AOA: | 2/1R |
| DEORBIT: | 2/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: K-SS4-U-T1-6CNX

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:

AN ERRONEOUS OUTPUT FROM THE WATER RELIEF NOZZLE TEMPERATURE SENSOR COULD PREVENT THE NOZZLE HEATER FROM WORKING. IF THE HEATER IS NONFUNCTIONAL, THE NOZZLE WOULD FREEZE. IF THE PRODUCT WATER LINE IS BLOCKED, ALL THE FUEL CELLS WILL FLOOD. WITH THE RELIEF NOZZLE BLOCKED, ONLY ONE PATH (PRODUCT WATER LINE) REMAINS OPEN BEFORE LOSS OF ALL FCP'S.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 2/1R
MDAC ID: 165 ABORT: 2/1R

ITEM: WATER NOZZLE
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:

- 1) EPG
- 2) FCP
- 3) ASA
- 4) WRS
- 5)
- 6)
- 7)
- 8)
- 9)

| CRITICALITIES | | | |
|-----------------|----------|-------|----------|
| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 2/1R | TAL: | 3/3 |
| ONORBIT: | 2/1R | AOA: | 2/1R |
| DEORBIT: | 2/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [1] B [NA] C [P]

LOCATION: MID-BODY
PART NUMBER: ME363-0042-0003

CAUSES: CONTAMINATION

EFFECTS/RATIONALE:

IF THE WATER NOZZLE BECOMES BLOCKED, THE WATER RELIEF FUNCTION IS LOST. WITH THE WATER NOZZLE BLOCKED, ONLY THE WATER LINE REMAINS OPERATIONAL BEFORE LOSS OF ALL FCP'S DUE TO FLOODING.

REFERENCES:

APENDIX D
POTENTIAL CRITICAL ITEMS

| <u>MDAC-ID</u> | <u>ITEM</u> | <u>FAILURE MODE</u> |
|----------------|---|--|
| 101 | Fuel Cell | Loss electrical contact in power section |
| 104 | End Cell Heater | Fail off |
| 105 | End Cell Heater | Fail on |
| 106 | Separator Plates/UEA | Reactant leakage to Orbiter (external leakage) |
| 107 | Separator Plates/UEA | Internal leakage |
| 108 | Separator Plates | Coolant leakage |
| 109 | Separator Plates | Reactant Blockage |
| 111 | Integrated Dual Gas Regulator | Gross Venting |
| 112 | Integrated Dual Gas Regulator | H2 overpressure |
| 113 | Integrated Dual Gas Regulator | H2 starvation |
| 114 | Integrated Dual Gas Regulator | O2 overpressure |
| 115 | Integrated Dual Gas Regulator | O2 starvation |
| 116 | Integrated Dual Gas Regulator | Purge failure |
| 117 | H2/O2 Lines and Fittings and Accessory Components | Reactant leakage to Orbiter (external leakage) |
| 118 | O2/H2 Purge-Vent Lines and Vent Nozzles | Restricted flow |
| 129 | Start-Up Heater | Fail on |
| 130 | H2/O2 Preheater | Restricted coolant flow |
| 131 | H2/O2 Preheater, Pump, Thermal Control Valve, Condenser, Filters, Start/Sustain Heater, Accumulator, Flexible Interface, ECLSS Heat Exchanger | |
| 132 | Coolant Pump | External leak of TCS coolant |
| 138 | Water Separator Pump | Loss of output |
| 139 | Water Separator Pump/ Water Condensate Trap | Degraded performance |
| 141 | Thermal Control Valve | Restricted flow |
| 142 | Water Discharge Valve | Erroneous Output |
| 143 | H2O Discharge | Fail closed |
| 148 | Product Water Line | Restricted flow |
| 149 | Water Supply Check Valve | External leakage |
| 151 | Water Supply Check Valve | Fails to check |
| 152 | Water Relief Valve | External leakage |

| <u>MDAC-ID</u> | <u>ITEM</u> | <u>FAILURE MODE</u> |
|----------------|---|---------------------|
| 159 | Water Relief (Vent) Line | Restricted flow |
| 163 | Water Nozzle Heater (A&B) | Fail off |
| 164 | Water Relief Nozzle Temperature Output | Erroneous output |
| 165 | Water Nozzle | Restricted flow |